THE COMMAND AND CONTROL – EMERGING EFFECTS FRAMEWORK: AN OVERVIEW

Submitted to the C2 Decision Making and Cognitive Analysis Track

by

Dr. Erik Jansen
Department of Information Sciences
Graduate School of Operations and Information Sciences
Naval Postgraduate School
Monterey, California, 93943
(831) 656-2623
ejansen@nps.navy.mil
Fax: (831) 656-3679

Professor [Emeritus] Carl R. Jones
Department of Information Sciences
Graduate School of Operations and Information Sciences
Naval Postgraduate School
Monterey, California, 93943
(831) 656-2995
crjones@nps.navy.mil
Fax: (831) 656-3679

Professor [Emeritus] Michael G. Sovereign
Department of Information Sciences
Graduate School of Operations and Information Sciences
Naval Postgraduate School
Monterey, California, 93943
(831) 656-3008
mgsovere@nps.navy.mil
Fax: 831.656.3679

POC: Dr. Erik Jansen

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2002**	2. REPORT TYPE	3. DATES COVERED **00-00-2002 to 00-00-2002**
4. TITLE AND SUBTITLE **The Command and Control - Emerging Effects Framework: An Overview**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Postgraduate School,Department of Information Sciences,Graduate School of Operations and Information Sciences,Monterey,CA,93943**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES **2002 Command and Control Research and Technology Symposium (CCRTS)**		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**		**16**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

THE COMMAND AND CONTROL – EMERGING EFFECTS FRAMEWORK: AN OVERVIEW

Erik Jansen
ejansen@nps.nav.mil

Carl R. Jones
crjones@nps.navy.mil

Michael G. Sovereign
msovereign@nps.navy.mil

Department of Information Sciences
Naval Postgraduate School
Monterey, California, 93943[1]

Abstract

The Command and Control – Emerging Effects (C2E2) framework describes a military force in an ecology of conflict and cooperation. The force's actions impact others, generating effects in a co-evolutionary process of emergent behavior patterns. The military force uses problem-focused processes to identify, solve, and implement its chosen solutions. Its organizational logic is the force-wide logic of its domain-specific, problem-focused processes. Its organizational architecture comprises the organizational logic with specifications for each logical task, roles for performing both manpower and technical tasks, incentives and coordination mechanisms, and structuring of tasks and roles into organizational units. Assigning resources (personnel and technical systems) to these roles and adjusting for role maladaptations requires control-coordination processes. These control-coordination processes, the science of C2, provide an infrastructure, (a "surface") on which the command process (the art of C2) operates. The command process involves a dialogue of deciding, leading, and interpreting among the commanders in the chain of command. The interactions engendered by the dialogue generate force-wide sensemaking processes and action capabilities that are the means for evolutionary adaptation to the ecology. The capability employs the adoption of a strategic posture and an operating point in the space of strategic fitness dimensions (edges).

INTRODUCTION

Rapid, significant changes are currently ubiquitous, including changes in the sciences that contribute to our understanding of military forces. Advances in organizational science and the science of complex adaptive systems can inform our understanding of military forces. We propose a Command and Control – Emerging Effects (C2E2) framework that incorporates new constructs and models, while building on past concepts (e.g., the fog of war, friction, risk, uncertainty and time-compressed operations). In this framework, the focal military force is embedded in an ecology of conflict and cooperation. Internally, the military force comprises control-coordination processes, which include the infrastructure of tactics, techniques, and procedures that provide a means for a commander's "exercise [of] authority and direction". As noted in Joint Vision 2020, these control-coordination processes are the science of command and control. The art of command and control is embodied in the command process in which commanders engage in a dialogue of deciding, leading and collaboration with superiors, subordinates,

[1] The authors thank the Naval Postgraduate School Institute for Joint Warfare Analysis for partial support for this research.

supporting commanders, and coalition partners. Metaphorically, the command process "rides" on the "surface" of control and coordination processes; it may thus "substitute" to some degree for maladaptations or failures in these processes.

The paper focuses first on the ecology of conflict and cooperation. Then, the discussion turns to internal operations, focusing on construct definitions. The military forces' control-coordination processes are considered before turning to the command process. The paper ends with a conceptual foundation for a commander to cope (be fit and mission successful) in an ecology of conflict and cooperation.[2]

THE ECOLOGY OF CONFLICT AND COOPERATION

A military force, such as a Joint Task Force, is a participant in an ecology of conflict and cooperation (hereafter the ecology). This ecology comprises individuals and organizations, which can be classified as friends, foes, or neutrals, situated in a physical environment. Friends include coalition partners, supporting organizations, and supported organizations. Foes include direct adversaries, adversary supporters, and long-term competitors. Neutrals include nation states, non-governmental organizations, the media, international organizations, and other organizations not involved in the conflict. These participants are called agents.

This ecology evolves through the mutual interactions of complex adaptive agents. Each of the agents, usually an organization, searches and seeks to achieve fitness within its ecology. From the agent's perspective, fitness ideally is identified with mission accomplishment. Searching and seeking ecological fitness involves problem identification, solution, and solution implementation. Agents are problem processors using problem-focused processes that begin with incomplete information and then, through sensemaking, develop a representation of the ecology. The sensemaking process is influenced by the organization's history and traditions. Based on its representations, courses of action are assessed, and, in the face of risk and uncertainty, one is chosen. The selected action is then implemented, impacting others in the ecology. During this process, agents anticipate other agents' actions, with each behaving strategically with respect to the others.

The impacts on other agents may be kinetic, psychological, or cybernetic. These impacts, in turn, generate effects in the internal operations of each of the agents. This "ecological cycle" continues as interaction processes proceed over time. Emerging from these interactions are broad behavioral patterns (e.g. maneuvers in space and time). Participants generally and imperfectly perceive these ecological patterns.

Ecological behavior can be analyzed in terms of equilibria, stability, and time-path. Notionally, equilibrium is characterized by "everything" being in balance: physical flows, human decision-making, and the actions taken by participants. In terms of decision making, an equilibrium occurs when there is no action that can be taken to

[2] This short exposition of the C2E2 framework focuses on major factors and their relationships. For ease of readability and to meet page constraints, only a book bibliography is provided with the most influential marked with an asterisk. A fully referenced version with figures is available from the authors. A book is in preparation.

improve the agent's ecological fitness, using that agent's own mission success criterion. This is Nash equilibrium. Stability refers to time-path behavior that returns the ecology to equilibrium. Stability can be local (that is, near an equilibrium) or global. Time-path behavior involves the complete story of the ecology as it evolves through time.

There are time-periods when little change occurs in these patterns and the agents "smoothly" adjust to one another. This ecological behavior is near equilibrium and locally stable. Each agent, while considering strategic behavior by other agents, operates through established routines with explicit and tacit decision rules that bound the range of possible actions. Other time-periods are turbulent, and the agents have difficulty adjusting to one another. Each agent, behaving strategically, searches to properly frame and make sense of its problems and enact its chosen solutions. Operations then are non-routine; they are fast paced, unpredictable, and exciting. Traditional decision rules are inadequate. Self-organization may be observed. "Butterfly" effects can occur per the old folk saying, "For want of the nail, the shoe was lost; for want of the shoe, the horse was lost…." A power law governs the magnitude and frequency of such turbulent periods. Small-scale changes are frequent, while large-scale changes are rare. This is "punctuated equilibrium". Note that ecological, time-path behavior may result in some agents exiting the ecology; all agents are not necessarily successful.

Overall, the ecology of conflict and cooperation evolves through interactions of strategically behaving agents, each seeking individual mission success (ecological fitness). Each agent uses internal, problem-focused processes that observe and develop representations of the ecology, and they decide on and implement courses of action. Ecological behavior can be analyzed in terms of equilibria, stability, and time path.

In some cases the ecology is characterized by a reduced set of parameters, such as complexity, dynamics (change), or hostility. These parameters then are used to study the actions of an agent, contingent on these parameters, with a local agent's view of equilibrium, stability, and time-path.

COMMAND AND CONTROL AND RELATED CONCEPTS

The various doctrinal definitions of "command and control" include (1) the core notion of "the exercise of authority and direction"; (2) a set of functions ("planning, directing, coordinating, and controlling"); and (3) a set of means ("personnel, equipment, communications, facilities, and procedures"). JV 2020 refers to command as the art and control as the science of command and control.

These ideas are the basis for the C2E2 generalization. Command as an art is the exercise of authority and direction. Control is viewed as an infrastructure, the set of processes that implement the functions ("planning, directing, coordinating, and controlling") using the means ("personnel, equipment, communications, facilities, and procedures"). In the C2E2 framework, the first is called the command process and the second the control-coordination processes. Command is a necessary hierarchical process for directing, leading, and collaborating. The art of command is most clearly revealed by the reality that it is a human process involving experience, intuition, judgment, and interpersonal and organizational competencies in a unique context requiring extensive tacit knowledge.

The processes referred to in the definition of command and control initially were formalized by Col. John Boyd (USAF) as the Observe, Orient, Decide, and Act (OODA) loop. This OODA loop is a process that comprises tasks (e.g. Observe is a task). More generally, it is a process that identifies problems (sensemaking), solves them, and implements the solution (e.g., maneuvering and shooting in space and time). In the C2E2 framework, these are called problem-focused processes (PFP). The sequence of OODA tasks can be expanded to sensing, processing, situation assessing and interpreting (sensemaking), problem identifying, alternative solution generating, deciding, implementing, and maneuvering and shooting in space and time (firing). Ecological interaction occurs through sensing and firing. Sensing is of collectible data in the ecology. Maneuvering and shooting in space and time generate impacts on other agents and hence on the total ecology.

The operational architecture, system architecture, and technical architecture of the Joint Technical Architecture serve as another basis for the C2E2 framework. The technical systems (e.g. C4ISR) in the military force are described in terms of the system and technical architectures. Platforms are an overlay on the system architecture. The operational architecture can be interpreted as an organizational structure comprising assigned personnel and equipment, operating processes (tactics, techniques, procedures) that perform planning, directing, coordinating, and controlling functional tasks, as well as maneuvering and shooting in space and time. This represents the control side of the science of command and control (JV 2020). The C2E2 framework generalizes this idea to the control-coordination processes, which provide the infrastructure of problem-focused processes needed to "exercise authority and direction".

THE MILITARY FORCE AS AN AGENT

To achieve ecological fitness, the military force functions as a problem processor. Problem processing is accomplished by organizing the military force into domain-specific problem-focused processes (e.g. air defense). This organizing process generates an infrastructure of control-coordination processes and a command process. The conventional characteristics of unity of effort and consistent execution are obtained mostly by the control-coordination processes. The characteristics of adaptation in ecology of conflict and cooperation is mostly obtained through the command process. The control-coordination processes are discussed first.

Analytically a military force's control-coordination processes involve an organizational logic and organizational architecture. The organizational logic is the military forces' mission (central problem to be solved) and the associated solution processes. This enterprise-level logic is disaggregated to domain-specific problem-focused processes (e.g. air defense), including the logical interdependencies among the domain-specific problem-focused processes. The organizational architecture comprises the organizational logic with (1) a description of how the individual process tasks will be performed including the roles with their manpower and technical systems requirements and (2) the control-coordination needed to cope with the inherent risk and uncertainty involved. The organizational architecture together with assigned resources (human and technical systems) forms the control-coordination processes. They are discussed in turn.

THE ORGANIZATIONAL LOGIC

At the enterprise level, there is a mission problem and an associated, generalized OODA process. This is the enterprise-level, problem-focused process. Disaggregation is used to develop domain-specific subproblems (with associated solution processes), as well as the logical interdependencies among the subproblems and their associated solution processes. This disaggregated, hierarchical structure of problems and solution processes (distributed problem solving) is called the process aggregation hierarchy and defines the organizational logic. For example, a process aggregation hierarchy could include a fire support process at the top level and the firing of an artillery piece process at the bottom task level. The levels are named (from the bottom): task, module, bundle, group, area, and macro-logic. The distinction among data, information, and knowledge is incorporated into the organization logic with a description for each variable involved. Risk and uncertainty are present at all levels of the process aggregation hierarchy. These ideas generalize the concepts associated with the Universal Joint Task List (UJTL).

A problem-focused process is associated with a specific problem in a specific knowledge domain at every level of the process aggregation hierarchy. A problem is simply a misfit between a goal(s) and the current situation as understood by sensemaking. Each problem structurally comprises (1) an evaluation criterion; (2) a relationship between inputs and outputs; (3) constraints; and (4) decision variables. Associated with each problem is a solution procedure (process) that searches the specific knowledge domain using either an algorithm or a heuristic. For the military force as a whole, algorithms are rare.

Problem-focused processes can be characterized in many dimensions. Of importance for the C2E2 model are (1) the analyzability of the problem and the solution process; (2) the variability of the process output (*ceteris paribus*); and (3) complexity. Traditional names based on the analyzability and variability characteristics are shown in Table 1.

Table 1
Traditional Problem-Focused Process Names

Analyzability	Variability	
	Low	High
High	Routine	Engineering
Low	Craft	Nonroutine

Complexity is a dimension of importance. The notion of complexity involves difficulty in identifying, solving, and implementing chosen solutions. Cognitive complexity focuses on the solution process, particularly using algorithmic information complexity measures. Relational complexity focuses on the interrelatedness of the process tasks. This is sometimes discussed in terms of task coupling. Finally, variety complexity focuses on the number of different types of process outputs. For example, a routine process has low variety, cognitive, and relational complexity. They are said to exhibit low overall complexity. Nonroutine processes are the opposite.

Problems may be categorized spatially, temporally, physically, functionally, by product or service produced, by resources, and computationally. The spatial, temporal and physical categories are well known and are not discussed here. The categories of product or service and resources focus on the interaction of the agent in the ecology (e.g. organizing by offense and defense). Computational categorization involves the characteristics of the process aggregation hierarchy.

As noted, subproblems and their associated solution processes (e.g., for force-wide coordinated fires) generally are logically interdependent. The interdependence categories are sequential, parallel, reciprocal (feedback), and pooled. The first three are well known, but pooled is not. It refers to the situation where many processes have a common input and that input is not consumed in the process of its use. An example is information in a database.

Selection of the "best" process aggregation hierarchy for a specific mission problem requires specification of criteria. Computational resources used are one criterion; the time to obtain an implemented solution is another.

The selected process aggregation hierarchy is implemented by organizing the military force to execute the logic. The process aggregation hierarchy must be embedded in the organized military force. The organizational logic serves as the fundamental basis for achieving unity of effort. The evaluation criterion for each subproblem ideally serve to properly set incentives for units and personnel assigned to perform specific tasks within a problem-focused process. These ideas are captured in the organizational architecture.

THE ORGANIZATIONAL ARCHITECTURE

The organizational logic, with its process aggregation hierarchy, is developed into the organizational architecture by specifying the means to perform each task, and then organizing the tasks into an organizational configuration.

Each task, following the IDEF_o format, is described by its workflow inputs, control inputs, resource inputs, workflow outputs, and the relationship among them. The relationship is called the task transformation function, which is usually nonlinear. The task transformation function describes the content of the tasks as required by the process aggregation hierarchy logic, including criteria that measure performance of the tasks. Some of the main characteristics of interest are shown in Table 2.

Table 2
Task Transformation Function Characteristics

Characteristic	Description
Scale	Changes in all outputs as all inputs change*
Productivity	Changes in one output as one input changes*
Substitution	Input for input, output for output*
Efficiency	Maximum output for a given level of inputs*
Effectiveness	Outputs that are ecologically fit*

**Ceteris paribus*

The specifications for the task resources are the human (manpower) and technical systems (hardware and software) requirements. To distinguish these architectural descriptions from assigned real physical resources, they are called roles. The specification of a manpower role includes requisite knowledge, skills, and competencies as well as decision authority and responsibilities. For technical systems the specification includes performance requirements and capacity.

Given the organizational logic and task descriptions, the process-focused processes can be organized into organizational units with a chain of command. The first tool for this organizing task is the organization responsibility-grouping chart (ORG Chart). It is a matrix showing the manpower roles on one side and the process aggregation hierarchy tasks on the other. Each manpower role with respect to a task is either (1) not involved; (2) directly performs; (3) supervises directly performing roles; (4) performs and supervises; and/or (5) hierarchically supervises roles supervising others. The ORG Chart defines the coordination architecture and its relationship to the workflow processes of the military force; it is the executable and logical infrastructure of the military force. Six coordination mechanisms (direct supervision, mutual adjustment, standardization of input, output or process, and ideology) serve to coordinate the interdependencies. For example, resource interdependence creates a need for coordination in the form of scheduling. The result of this role – task assignment (ORG Chart) method is a chain of command and organizational units, with defined tasks, decision authorities, solution processes, and evaluation criteria (incentive schema). The traditional organizational configurations (types) that emerge are: simple, functional, divisional, matrix, machine bureaucracy, ad hoc, and professional bureaucracy. Structuring the organization logic into a chain of command and units results in the organizational architecture. It is the fundamental architecture for the command and control-coordination processes and is based on organizational and physical science.

THE CONTROL- COORDINATION PROCESSES

An organizational architecture resourced with personnel and technical systems is an operational architecture. These human and technical resources functioning in their roles can generate unanticipated consequences and maladaptations. For example, the planned, "to be" architecture with its role specifications may not be resource or incentive feasible. Individuals assigned to command or other roles may have personal goals that are not

synchronized with the organization’s mission and goals. This incentive compatibility problem creates the need for additional coordination.

Incentive compatibility, sometimes called “careerism”, can be a serious problem in organizations. An analytical approach to understanding the problem is called agency theory (or principal-agent theory). The supervisor may be viewed as the principal, and the supervisee as the agent. The agent has information unavailable to the principal (information asymmetry). The incentive problems include the following. (1) What incentive structure will generate agent behavior exactly like the behavior that would be chosen by the principal in the same circumstances? (2) How should risk be shared? The C2E2 framework incorporates understanding of potential agency problems.

Interdependence can arise from various sources. In terms of organizational logic and organizational architecture, coordination techniques are “designed in” as needed. When resources are assigned, adaptation may be needed, given that resources may not satisfy role specifications. For example, if a resource with an overall capacity constraint is assigned to multiple roles, resource interdependence occurs. This interdependence must be coordinated. In addition, the ecology can present unanticipated problems. Some assigned human resources may not match role specifications. The result is the need to coordinate in reassigning personnel or to change the organization logic. These maladaptation interdependencies must be coordinated by one or more of the six coordination techniques already noted. For example, scheduling can coordinate resource interdependence. Scheduling can be accomplished by assigning the coordination task to the direct supervisor (chain of command) of all the resource interdependent tasks, which sometimes occurs high in the hierarchy (e.g. a JTF commander). Alternatively, the supervisors of the individual tasks, now resource interdependent, could be assigned the coordination responsibilities of mutual adjustment. Another solution would be to coordinate through decision rules that standardize scheduling. Finally, doctrine could be written to frame scheduling problems into generalizable solutions that actors can use in real time. Combinations of the coordination techniques are possible. In general the types of interdependencies are associated with coordination techniques as shown in Table 3 along with demands on communication and collocation of the personnel.

Table 3
Interdependence and Coordination Techniques

Interdependence Type	Coordination Type	Communication Demand	Priority For Close Unit Location
Pooled	Ideology, standardization (rules, procedures)	Low	Low
Sequential	Standardization (plans, schedules); mutual adjustment (liaison)	Medium	Medium
Reciprocal	Direct supervision, mutual adjustment (unscheduled meetings)	High	High
Parallel (None)	None	None	None

Another type of control-coordination is cybernetic control or feedback control. There are four operational modes for cybernetic control. The drivers of three types of modal behavior are the degree of analyzability of the process being controlled and the measurability of that process's output. Table 4 shows the relationship.

Table 4
Cybernetic Control Modes

Output Measurability	Controlled Process Analyzability	
	Low	High
High	Output control	Process or output control
Low	Clan control	Process control

Output control occurs by setting output and monitoring goals. Process control occurs by formalizing the process and centralizing the development of the process procedures. These two modes rely on explicit knowledge. Clan control, which includes norms, rituals, conventions, and "symbolic" behavior (e.g., expressed beliefs), relies on social interaction and tacit knowledge. A fourth type of control, input control, also can generate control-coordination by setting constraints (bounds) on resources, which in turn upper-bound the capacity for performing a task.

Some maladaptations involve the logic of the problem-focused process. This can occur because resources do not match the role specifications; decreased task performance thus may require the development of a new logic. Alternatively as the ecology evolves, a maladaptation can occur because the existing organizational logic does not match problems in the evolved ecology. The ORG Chart and the organizational logic can be used to identify and cope with this condition.

Other maladaptations of interest are authority-task gaps and virtual positions. Inconsistencies between the organizational logic, organizational architecture, and the

control-coordination processes drive the emergence of authority-task gaps. Although most are unrecognized or simply tolerated, some are substantial. Authority-task gaps can provide checks and balances, but they are more typically emergent, unanticipated results of interactions that create an evolutionary path of inconsistencies. They flourish when resources are plentiful and coordination of "everything" becomes a goal. Authority-task gaps become authority-task problems when resources change or ecological fitness decreases (mission success is threatened). The existence of committees (standing or ad hoc) and multiple meetings suggest that authority-task gaps and problems exist. Their resolution evolves the organization toward fitness and improved unity of effort.

A virtual position is a composite of positions (both roles and resources) involved in a process that is not tied to any supervisor in the chain of command. More precisely, a virtual position represents a set of tasks performed by a composite entity (super-role) of three or more roles. Standing committees are an example of a virtual position. When officially recognized, they are called regulated virtual positions. Virtual positions emerge to cope with change and are associated with conflict and power struggles as they are "orthogonal" to established processes.

The discussion now turns briefly to the commanders and staffs as integral and critical parts of the control-coordination processes. Commanders are discussed first. From a decision-making perspective, commanders use two logics: the logic of consequences and the logic of appropriateness. The logic of consequences refers to deductive rationality exemplified by the engineering problem-solving method. The logic of appropriateness is a non-calculative rationality. It is exemplified by recognition-primed decisionmaking. (Decisions are made by matching the observed situation to an appropriate action. Matching is a pattern recognition mental process. The matching pattern is learned through education, training, and life experiences.) With experience, commanders gain tacit and explicit knowledge that manifests itself in terms of technical and interpersonal competencies. This knowledge, when combined with motivation and personality, shape individual level contributions of the commander to the coordination processes. Of particular import is the emergence of trust. Commanders deal with the principal – agent problem as both principal and agent. Pathologies (authoritarianism, manipulation, paternalism, permissivism) are ever-present potential individual weaknesses that can compromise the command process (and hence the control-coordination processes).

Effective teams require some degree of trust, which emerges from members' interactions. Teams enhance knowledge sharing and integration and so are suited to resolving complex problems. Although teams increase problem-solving capacity, they require autonomous coordination, which is learned through experience and training. Pathologies (e.g. group pressure toward blind acquiescence and conformity, groupthink, and an attitude toward risk that leads to riskier solutions) can occur.

The control-coordination processes are the infrastructure that enables command, as an art, to flourish or fail. The organizational logic and architectures, when instantiated by human (manpower) and technical systems resources, along with the necessary adjustments to them, enable the commander to adapt the force to an evolving ecology.

THE COMMAND PROCESS

The command process involves deciding, leading and collaborating. It is executed by humans. It is observable as a dialogue among superiors, subordinates, and equals. As noted in JV 2020, it is the art of command and control. Metaphorically, it "rides" on the "surface" of the control-coordination processes.

Each commander assumes command with knowledge and an ability to understand based on a lifetime of experience, education, and training. Military professional schooling and training shape commanders to share doctrine and thought processes. Stated in terms of coordination techniques, commanders are coordinated by a learned ideology. A commander "exercises authority and direction" using a dialogue involving decisionmaking, leading, and collaborating. Decision-making has been discussed. Leading is well known with many aspects. Collaboration is increasingly critical as it is central to many coalition operations. Collaboration is frequently accomplished through negotiation. Negotiation also is appropriate for interactions with non-DoD agencies and departments and supporting commands. In the ecology of cooperation and conflict, negotiation and the needs for collaboration typically derive from incentive incompatibilities and the tradeoffs required to choose and take actions. Collaboration with negotiation is the process of seeking agreements on these tradeoffs. The concept of dialogue becomes central here; it also includes giving orders, seeking advice, and stating commander's intent. Dialogue is not created *de nova* by each commander, but is structured (templated) by the ideology of doctrine and TTPs.

The deciding, leading, and collaboration dialogue is inherently a social process. The representation of the ecology used for decision-making is based on collected data processed into information. Sensemaking is an interpretive social process that results in a socially constructed representation of the ecology (and the internal organization). As the command process proceeds through time, it is enfolded with other control-coordination processes and a force-wide social cognition, interpretation and action capability emerges from the interactions among the commanders in the chain of command and their staffs. This emergent force-wide social cognition, interpretation and action capability provides the basis for fitness in the ecology. This capability can change over time as personnel or technical systems change and as the ecology evolves. Battle group workups are an example of using training to focus the command dialogue and evolve the force-wide social cognition, interpretation and action capability.

COPING IN THE ECOLOGY OF CONFLICT AND COOPERATION

The command and other control-coordination processes are present and operating in each of the organizational agents in the ecology. Each agent searches for ecological fitness in terms of its own self-referential, fitness criterion (i.e., mission success as they interpret it). From the agent's perspective, this search process works on a strategy-action landscape using enterprise-level problem-focused processes. Metaphorically, the strategy-action landscape comprises peaks, mountains, plains, and valleys. For simplicity, consider the vertical axis to be a measure of mission success (e.g. probability of mission success). So higher "up the hill" improves ecological fitness. Strategy-action descriptions constitute the other dimensions. The shape of the landscape is driven by (1) the organization's

command process and control-coordination processes and its emergent force-wide social cognition, interpretation, and collaboration capability; (2) the physical environment; and (3) the friends, foes and neutrals strategies, as interpreted by the agent.

Changes in an agent's own organization changes the landscape. As the physical environment changes (e.g. warfare effects, change of venue), the landscape changes. As others in the ecology change strategies, the landscape changes. Sometime the changes are plentiful and fast (far from equilibrium behavior). Other times, changes are few and slow (locally stable, near an equilibrium). The changes in the landscape are the dynamics of the inter-organizational interactions in the ecology. To search its landscape, each agent, usually an organization, depends upon its force-wide social cognition, interpretation, and collaboration capability for the search. As each agent in the ecology searches the strategic landscape and acts, all agents are impacted, and their strategic landscape changes. Broad patterns (e.g. battlefield flow patterns) emerge from these interactions. Depending on the agents' characteristics and their interactions, the ecology may have equilibria, be stable, and have time-paths that are near equilibrium.

The C2E2 framework describes the behavioral characteristics of such these problem-focused (search) processes according to the (1) the analyzability of the process and (2) consensus regarding the problem formulation (equivocality). This is shown in Table 5. (Note that these behavioral concepts also apply to purely internal problem-focused process behaviors.) "Management Science" behavior is almost algorithmic and mechanical; it searches locally in the landscape. "Incremental" processes focus on the means to solve an agreed upon problem. They are typified by local search and multiple "trial and error" iterations. A "garbage can" (a technical name) process searches large parts of the landscape seeking both a problem formulation and a solution. It is far from equilibrium behavior. It is typified by coalitional behavior, bargaining, and opportunistic action in the context of fixed decision deadlines. Finally "Carnegie" processes search for the problem formulation, given the capability to solve a large menu of problems. This type of search is local and typified by coalitional behavior, bargaining, and opportunistic action.

Table 5
Systematic Behavior of Problem-Focused Processes

Ambiguity	Equivocality	
	Low	High
High	Incremental (Engineering)	Garbage can
Low	Management science	Carnegie

The strategic problem-focused process includes problem identification and framing as well as finding solutions in the space of strategy dimensions. There are several possible generic strategic postures or types, which are defender, prospector, analyzer, hybrids of these three, or reactor. These strategic postures involve tradeoffs and dilemmas at ecological fitness "edges". These are described in Table 6. Note that they deal with the problems of command: adaptation, consistent execution, and unity of effort. The operating values for these edges (dimensions) are found by evolutionary search.

Table 6
The Edges of Fitness

Fitness edge	Dilemma
Improvisation	Adaptively innovate vs. Consistently execute without falling into either a chaos trap or a bureaucracy trap
Experimentation	Commitment to a future vs. Flexibility for a future without falling into either a foresight trap or a no-sight trap
Regeneration	Exploit the old vs. Explore the new without falling into the over-connected trap or the disconnected trap
Co-adaptation	Collaborative synergies vs. Individual success without falling into either the lockstep trap or the star trap
Chaos	Be in the most adaptable state at the edge of chaos without falling over it.
Time	Steering by the wake or steering by a fantastical future. Adaptation requires thinking about multiple time horizons at the same time

In general, operational military forces (e.g. Joint Task Forces) are temporary organizations designed for specific missions. The assigned forces are existing operational units from the services. Each has a command process and control-coordination processes with an emergent, force-wide, social cognition, interpretation, and collaboration capability. The force commander must co-create these problem-focused processes to integrate these forces. Commanders in the chain of command each adjust their organizational logic and organizational architecture to create the control-coordination processes that are resource feasible. Authority-task gaps and problems and virtual positions are created, tolerated, and eliminated in the search for the ecologically fit, resource feasible control-coordination processes. The organizational logic sometimes is modified in specific knowledge domains to accommodate the available resources. The evolved logic may not be an ecological fit. Roles may be redefined to fit the characteristics of assigned personnel. This can reduce the ability to adapt and consistently execute. The force-wide social cognition, interpretation, and collaboration capability may decrease. The overall commander, operating through the command process and enabled by the force's organizational logic and architecture, seeks to integrate (e.g. using a common operating picture) these separate, possibly divergent, evolutionary command and control-coordination processes to achieve mission success (ecological fitness). In so doing, the commander becomes a critical part of the process that searches the strategic landscape. Issues of incentive incompatibility, ideological incompatibility (e.g. service perspectives) and physical incompatibilities need to be overcome. The on-going efforts with a standing joint force headquarters exemplify the importance and difficulty of the problem. This example is an indication of the type of military force behavior where the C2E2 framework can assist in informing a commander's decisionmaking. Finally, its complexity suggests why command and control is both art and science as emerging, adaptive systems effects become paramount. Future papers and monographs will expand the exposition of the framework and provide detailed references and applications.

SELECTED BOOK BIBLIOGRAPHY

Alberts, D., and R. Hayes, *Command Arrangements for Peace Operations*, 1995.

Argote, L., *Organizational Learning: Creating, Retaining and Transferring Knowledge*, 1999.

Axelrod, R., *The Complexity of Cooperation: Agent-Based Models of Competition and Collaboration*, 1997.

Brown, Shona L. and Kathleen M. Eisenhardt, *Competing on the Edge: Strategy as Structured Chaos*, 1998 *

Builder, Carl, Steven C. Bankes, and Richard Nordin, *Command Concepts: A Theory Derived from the Practice of Command and Control*, 1999.

Burton, Richard M., and Borge Obel, *Strategic Organizational Diagnosis and Design: Developing Theory for Application*, Second Edition, 1998. *

Burt, Ronald S., *Structural Holes: The Social Structure of Competition*, 1992.

Carley, K.M., and M.J. Prietula, *Computational Organization Theory*, 1994.

Chwe, Michael Suk-Young, *Rational Ritual: Culture, Coordination, and Common Knowledge*, 2001.

Cohen, Eliot A. and John Gooch, *Military Misfortunes: The Anatomy of Failure in War*, 1990.

Cohen, Michael D., and Lee S. Sproull, editors, *Organizational Learning*, 1996.

Coveney, Peter, and Roger Highfield, *Frontiers of Complexity: The Search for Order in a Chaotic World*, 1995.

Durlauf, Steven N., and H. Peyton Young, editors, *Social Dynamics*, 2001.

Czerwinske, Tom, *Coping with the Bounds: Speculations on Nonlinearity in Military Affairs*, 1998. *

Elzinga, D. Jack, Thomas R. Gulledge, and Chung-Yee Lee, *Business Process Engineering: Advancing the State of the Art*, 1999.

Epstein, J., and R. Axtell, *Growing Artificial Societies: Social Science from the Bottom Up*, 1996. *

Eve, Raymond, Sara Horsfall, and Mary E. Lee, editors, C*haos, Complexity, and Sociology: Myths, Models, and Theories*, 1997.

Flake, Gary William, *The Computational Beauty of Nature: Computer Explorations of Fractals, Chaos, Complex Systems, and Adaptation*, 1998.

Ferber, Jacques, *Multi-Agent Systems: An Introduction to Distributed Artificial Intelligence*, 1999.

Grandori, Anna, *Organization and Economic Behavior*, 2001. *

James, Glenn E. (Major, USAF), *Chaos Theory: The Essentials for Military Applications*, Newport Papers, No. 10, Naval War College, 1996.

Joint Chiefs of Staff, *Universal Joint Task List*, CJCSM 3500.04B, 1999. *

Joint Chiefs of Staff, *Joint Vision 2020*, http://www.dtic.mil/jv2020/ *

Kauffman, Stuart A., *Origins of Order*, 1993.

Klein, Gary, *Sources of Power: How People Make Decisions*, 1998. *

Kohler, Timothy A., and George J. Gumerman, *Dynamics in Human and Primate Societies: Agent-Based Modeling of Social and Spatial Processes*, 2000.

Lesourne, Jacques, *The Economics of Order and Disorder*, 1992.

Mackenzie, Kenneth D., *The Organizational Hologram: The Effective Management of Organizational Change*, 1991. *

March, James, G., and R. Weissinger-Baylon, *Ambiguity and Command: Organizational Perspectives on Military Decision Making*, 1986.

March, James G., *A Primer on Decision Making: How Decisions Happen*, 1994. *

March, James G., *The Pursuit of Organizational Intelligence*, 1999.

March, James G., Martin Schulz, and Xueguang Zhou, *The Dynamics of Rules: Change in Written Organizational Codes*¸ 2000. *

Marion, Russ, *The Edge of Organization: Chaos and Complexity Theories of Formal Social Systems*, 1999.

Milner, Robin, *Communication and Concurrency*, 1989.

Mintzberg, H., *Structures in Five: Designing Effective Organizations, 1983*. *

Page-Jones, M., *A Practical Guide to Structured System Design*, Second Edition, 1988.

Pressman, Roger S., *Software Engineering*, 1987.

Prietula, Michael, Kathleen M. Carley, and Les Gasser, *Simulating Organizations: Computational Models of Institutions and Groups*, 1998. *

Prigogine, Ilya, and Isabelle Stengers, *Order out of Chaos: Man's New Dialogue with Nature*, 1984.

Snook, Scott A., *Friendly Fire: The Accidental Shootdown of U.S. Black Hawks over Northern Iraq*, 2000.

Stacey, Ralph D., *Complex Responsive Processes in Organizations: Learning and Knowledge Creation*, 2001. *

Taylor, James R., and Elizabeth J. Van Every, *The Emergent Organization: Communication as Its Site and Sound*, 2000. *

U.S. Marine Corps, *Command and Control*, circa 1995. *

U.S. Navy, *Naval Command and Control*, Naval Doctrine Publication 6, 1995.

Van Creveld, Martin, *Command in War*, 1985. *

Warglien, Massimo, and Michael Masuch, editors, *The Logic of Organizational Disorder*, 1996.

Wasserman, Stanley, and Katherine Faust, *Social Network Analysis: Methods and Applications*, 1994.

Weiss, Gernard, editor, *Multiagent Systems: A Modern Approach to Distributed Artificial Intelligence*, 1999.

Weick, Karl E., *Sensemaking in Organizations*, 1995. *

Young, H. Peyton, *Individual Strategy and Social Structure: An Evolutionary Theory of Institutions*, 1998.